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ARM Facilities Newsletter

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Atmospheric Radiation Measurement Program

ARM

Energy Balance Bowen Ratio System

Estimates of surface energy fluxes are a primary product of the data collection systems at the ARM SGP CART site. Surface fluxes tell researchers a great deal about the effects of interactions between the sun's energy and Earth.

Surface fluxes of latent and sensible heat can be estimated by measuring temperature and relative humidity gradients across a vertical distance. Sensible heat is what we feel coming from a warm sidewalk or a metal car door; it can be measured with a thermometer. Latent heat, on the other hand, is released or absorbed during transformations such as the freezing of water into ice or the evaporation of morning dew from a lawn. Such a transformation is referred to as a "phase change," the conversion of a substance among its solid, liquid, and vapor phases.

Phase change is an important aspect of our climate. Earth's water cycle abounds with phase changes: rain falls and evaporates, changing from liquid to vapor; the water vapor in the air condenses to form clouds, changing from a gas into a liquid cloud droplet, and eventually falls to Earth's surface as rain or snow; snow falls and melts to liquid or sublimes directly to water vapor. This cyclic process has no end.

Surface vegetation and land use play extremely important roles in surface energy fluxes. Plants absorb and reflect solar radiation and also take up water and expel water vapor. The type of plant material, its stage of growth, and its color determine whether and to what extent the surface and air can couple and exchange energy.

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One type of instrument that ARM uses to measure surface fluxes is called an Energy Balance Bowen Ratio (EBBR) system. This ground-based system calculates vertical fluxes of sensible and latent heat at the surface by using measured values of net radiation and soil heat flow, along with vertical gradients of temperature and relative humidity. Fourteen EBBR stations are currently in use at the CART site, all at extended facility locations.

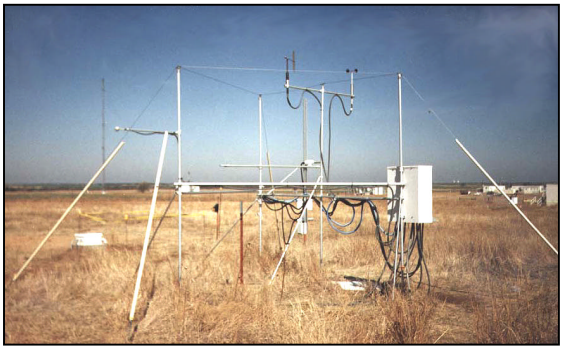

Figure 1. A typical Energy Balance Bowen Ratio (EBBR) system used for surface flux measurements.

Energy at Earth's surface is governed by the energy balance equation, which states that incoming and outgoing energy fluxes are equal. That is, the amount of net radiation (incoming and outgoing, solar and infrared) is equal to the sum of latent, sensible, and ground heat fluxes. Use of the EBBR enables calculation of a value called the Bowen ratio, which helps scientists determine the partitioning between latent and sensible heat fluxes. The Bowen ratio is a critical initializing value in the world of climate modeling.

The EBBR system incorporates individual instruments that measure the quantities required to estimate energy and moisture exchanges between the ground and the atmosphere directly above it. Data on air temperature, relative humidity, soil temperature, soil moisture, soil heat flow, barometric pressure, net solar radiation, wind speed, and wind direction are collected by individual sensors and recorded by a data logger. Air temperature and relative humidity probes are mounted in pairs inside solar radiation shields. The probes are placed one meter apart vertically on separate arms; an automatic exchange mechanism (AEM) causes the arms to exchange places (upper moves to lower and vice versa) at 15-minute intervals. The AEM reduces errors that might be introduced into the data set through instrument calibration. If the arms do not complete their exchange, the measurements are flagged to alert the data user to potential inaccuracies.

One ARM goal is to understand how clouds affect climate, and clouds are a result of surface fluxes. Characterizing surface fluxes by using the EBBR system improves our knowledge of the relationship between clouds and climate and moves ARM scientists toward that goal.